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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant : Michiel Jacques van Nieuwstadt   Art Unit : 3748

Serial No. : 09/682,443   Examiner : T. Nguyen

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Title : METHODS AND APPARATUS FOR CONTROLLING HYDROCARBON INJECTION INTO ENGINE EXHAUST TO REDUCE NOX

Commissioner of Patents
Washington, DC 20231

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Tanya Blount
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APPEAL BRIEF

(1) Real party in interest.

The real party in interest is the Assignee, Ford Global Technologies, Inc., a corporation organized and existing by virtue of the laws of the State of Michigan, having its principal place of business at Dearborn, County of Wayne, and State of Michigan which is a wholly owned subsidiary of Ford Motor Company, a Delaware corporation.

(2) Related appeals and interferences.

There are no related appeals or interferences.

(3) Status of claims.

Claims1 and 4-11 are under final rejection.

No claims are allowed.

No claims are objected to.

(4) Status of amendments

An amendment mailed July 31. 2002 after the final rejection of June 19, 2002 was entered upon the filing of the Notice of Appeal as indicated in paragraph 7 of the advisory action mailed August 12, 2002.

(5) Summary of Invention

Referring now to FIG. 2, a functional block diagram of an exhaust system 10 for reducing and controlling hydrocarbon (HC) injection into the exhaust 12 of an engine 14 via an HC injector 18 to reduce NOx in such exhaust is shown. The system 10 includes a catalyst 24 to facilitate the reaction between the HC and the NOx in the engine exhaust. More particularly, the system 10 includes the injector18 for introducing hydrocarbons (HC) into the exhaust 18 in response to a control signal fed to the injector 18 on line 19 in a manner to be described in more detail hereinafter. Suffice it to say here that while the temperature T_CAT_OPTIMUM at which the hydrocarbon should react with the NOx in the exhaust for maximum NOx reduction efficiency may be established for a new or so-called green catalyst, as shown FIG. 1, the temperature T_CAT_OPTIMUM for optimum NOx reduction efficiency increases with catalyst age

Thus, if the computed exotherm T_exo exceeds a threshold level T_exo_thres, the light-off temperature, T_lo, (i.e., the temperature produced by the upstr sensor 20 when the computed exotherm T_exo exceeds the threshold level T_exo_thres) is detected and such light-off signal T_lo is passed through a gate 30 to a subtractor 32. Gate 30 is an enabled gate to close temporarily when its enabling input exhibits a rising edge from negative to positive; otherwise it is open. This light-off temperature, T_lo which passes through gate 30 when such gate is temporarily closed, is compared with the light-off temperature expected for the catalyst 24 when such catalyst 24 was green; i.e., an expected light-off temperature T_lo_exp_green. This expected light-off temperature, T_lo_exp_green, is a function of total exhaust flow. Thus

T_lo_exp_green (i.e., T_CAT_OPTIMUM) as a function of total exhaust flow is stored in a look-up table 35. The table 35 is fed the actual total exhaust flow by a sensor disposed in the engine intake air system. The output of the look-up table 35 is thus the light -off temperature expected for a green catalyst, i.e., T_lo_exp_green. This temperature T_lo_exp_green, along with the actual light-off temperature T_lo of the catalyst 24 (which was passed through gate 30) are fed to the subtractor 32. The subtractor 32 computes T_lo_diff = T_lo-T_lo_exp_green (i.e., the difference between the actual light-off temperature of catalyst 24 and the light-off temperature expected for a green catalyst). Thus, T_lo_diff is, as described above, a function of the aging of the catalyst 24 and particularly the effect of aging of the catalyst 24 on the optimum conversion temperature T_CAT_OPTIMUM (FIG. 1)

This difference T_lo_diff is used to compute f2 for multiplication with f1 produced by the look-up table 27 and thereby produce the correct control signal on line 19 for the HC injector 18. A look-up table 27 is provided to store the function f1 described above, such function f1 being a function of RPM, SV, start of injection (SOI), exhaust gas recirculation (EGR) and fuel. More particularly, the function f2 for a green catalyst must be shifted as described above in connection with FIG. 2 so that f2 produced by a calculator 39 is equal to f2 where f2 is the curve 17 of FIG. 3 shifted in temperature T_lo_diff, here 20 degrees C to produce curve 19 in FIG. 3.

f2 = a fcn of cat. temp only

To put it another way, T_lo_diff = T_lo - T_lo_exp_green (i.e., where T_lo is the current light-off temperature of the catalyst 24 and T_lo_exp_green is the light-off temperature of the catalyst prior to its aging). The function multiplied by f1 in multiplier 29 is f2 for a green catalyst shifted in temperature by T_lo_diff. Thus, the calculator 39 produces f2 for multiplication with f1 in multiplier 29 which is a function of temperature in accordance with the curve 19 in FIG. 3 if, for example, T_lo_diff = 20 degrees C.

The calculator 39 includes an integration to make T_lo_diff depend not only on the last recorded light-off (i.e., T_lo), but the average off the last few light-off events. Thus, the calculator computes the temperature for peak NOx conversion efficiency in accordance with T_lo(k) =T_lo(k+1)+ki*T_lo_diff, where ki is a calibration gain less than one. Thus, f2 = f2 for a green catalyst shifted in temperature by T_lo_diff =T_lo(k+1)-T_lo_exp_green.

Referring to FIG. 3, it is noted that the temperature (i.e. T_CAT_OPTIMUM) at which there is optimum NOx reduction for a new catalyst is here, in this example, about 200 degrees Centigrade, as shown by curve 13, while for an aged catalyst the temperature (i.e.

also see Fig. 7 of Hirota

T_CAT_OPTIMUM) for optimum NOx conversion efficiency has increased to 220 degrees Centigrade or shifted by 20 degrees Centigrade, as shown by curve 15. Further, it is noted that at optimum conversion temperature, the proper amount of hydrocarbon to be injected may be determined a priori from such things as engine speed, engine load, EGR level, etc. However, this proper amount of hydrocarbon injection is reduced by a factor K, (where K is 1.0 between T1 and T2 and < 1 for temperatures other than the optimum conversion temperature. More particularly, for the catalyst shown in FIG. 3, and referring also to FIG. 1, f2 in FIG. 2 has a value of 0 for catalyst temperatures less than T_LOW, here 180 degrees C for a green catalyst and 200 degrees C after the green catalyst has aged and catalyst temperatures greater than T_HIGH, here 250 for the green catalyst and 270 degrees C after the green catalyst has aged. The function f2 in FIG. 3 is 1.0 between catalyst temperature T1 and T2, where the optimum conversion temperature T_CAT_OPTIMUM for the particular catalyst shown in FIG. 1 is between T1 and T2. Here, for the catalyst shown in FIG. 3, T1 is 180 degrees C for the green catalyst and increases to 200 degrees C after it has aged, T2 is 210 degrees C for the green catalyst and increases to 230 degrees C after it has aged. Thus, T_CAT_OPTIMUM for the green catalyst in FIG. 3 is here 200 degrees C and shifts to 220 degrees C after aging as shown in FIG.3. As noted above in connection with FIG. 1, the function f2 monotonically increases from 0 to 1 between T_LOW and T1 and monotonically decreases from 1 to 0 between T2 and T_HIGH.

Thus, for optimum conversion, one needs to know the curve f2 as a function of catalyst temperature and, as noted above and from FIG. 3, the shift in f2 with the age of the catalyst 24. Here, the processor 24 determines the optimum conversion temperature of an aged catalyst and thus the processor is able to determine that proper function f2 for such aged catalyst. That is, if the factor f2 is tuned for a green catalyst, such factor f2 is sub-optimal for the aged catalyst. A knowledge of the optimal conversion temperature for the aged catalyst would however enable optimal selection of the factor f2.

i.e., a fcn of deteriorated level of cat.

The processor 26 produces the function f2 as a function of aging of the catalyst 24 conversion efficiency in a manner to be described and then multiplies the function f2 with the function f1 from table 27 in multiplier 29. It is first noted that the level of the hydrocarbon injected into the exhaust is checked to determine whether it is above a minimum level to insure that an exothermic reaction can be expected. If there is such a minimum level of HC, the

processor computes the exotherm T_exo=T-dnstr-T_upstr in a subtractor 31 in response to the signals produced by the temperature sensors 22, 20, respectively. If the computed exotherm T_exo exceeds a threshold level T_exo_thres, the light-off temperature, T_lo, (i.e., the temperature produced by the upstr sensor 20 when the computed exotherm T_exo exceeds the threshold level T_exo_thres) is detected and such light-off signal T_lo is passed through a gate 30 to a subtractor 32. Gate 30 is an enabled gate to close temporarily when its enabling input exhibits a rising edge from negative to positive; otherwise it is open. This light-off temperature, T_lo which passes through gate 30 when such gate is temporarily closed, is compared with the light-off temperature expected for the catalyst 24 when such catalyst 24 was green; i.e., an expected light-off temperature T_lo_exp_green. This expected light-off temperature, T_lo_exp_green, is a function of total exhaust flow. Thus T_lo_exp_green (i.e., T_CAT_OPTIMUM) as a function of total exhaust flow is stored in a look-up table 35. The table 35 is fed the actual total exhaust flow by a sensor disposed in the engine intake air system . The output of the look-up table 35 is thus the light -off temperature expected for a green catalyst, i.e., T_lo_exp_green. This temperature T_lo_exp_green, along with the actual light-off temperature T_lo of the catalyst 24 (which was passed through gate 30) are fed to the subtractor 32. The subtractor 32 computes T_lo_diff = T_lo-T_lo_exp_green (i.e., the difference between the actual light-off temperature of catalyst 24 and the light-off temperature expected for a green catalyst). Thus, T_lo_diff is, as described above, a function of the aging of the catalyst 24 and particularly the effect of aging of the catalyst 24 on the optimum conversion temperature T_CAT_OPTIMUM (FIG. 1)

This difference T_lo_diff is used to compute f2 for multiplication with f1 produced by the look-up table 27 and thereby produce the correct control signal on line 19 for the HC injector 18. More particularly, the function f2 for a green catalyst must be shifted as described above in connection with FIG. 2 so that f2 produced by a calculator 39 is equal to f2 where f2 is the curve 17 of FIG. 3 shifted in temperature T_lo_diff, here 20 degrees C to produce curve 19 in FIG. 3.

To put it another way, T_lo_diff = T_lo - T_lo_exp_green (i.e., where T_lo is the current light-off temperature of the catalyst 24 and T_lo_exp_green is the light-off temperature of the catalyst prior to its aging). The function multiplied by f1 in multiplier 29 is f2 for a green catalyst shifted in temperature by T_lo_diff. Thus, the calculator 39 produces f2 for

multiplication with f1 in multiplier 29 which is a function of temperature in accordance with the curve 19 in FIG. 3 if, for example, T_lo_diff = 20 degrees C.

The calculator 39 includes an integration to make T_lo_diff depend not only on the last recorded light-off (i.e., T_lo), but the average off the last few light-off events. Thus, the calculator computes the temperature for peak NOx conversion efficiency in accordance with T_lo(k) =T_lo(k+1)+ki*T_lo_diff, where ki is a calibration gain less than one. Thus, f2 = f2 for a green catalyst shifted in temperature by T_lo_diff =T_lo(k+1)-T_lo_exp_green.

Thus, the processor 26 takes advantage of the property that from basic chemical kinetics the temperature for maximum NOx conversion coincides with the temperature of hydrocarbon light-off (i.e., the light-off temperature is the temperature when the hydrocarbons –O2 reaction occurs). The light-off event can be detected because when there is this hydrocarbon-O2 reaction, such reaction is an exothermic reaction and thus heat is generated and given off. The generation of such heat may be detected by here measuring the difference in temperature across the catalyst. Reference is made to FIG. 4 which shows the fractional portion of HC burned as a function of temperature and NOx conversion efficiency as a function of temperature. Thus, it is noted from FIG. 4 that the peak in NOx conversion efficiency occurs at substantially the same temperature as when there is an exotherm or burning of the HC, here at about 200 degrees C. Thus, peak NOx conversion efficiency and HC light-off coincide at substantially the same temperature.

(6) <u>Issue</u>

(A) Whether claim 1 is anticipated by King et al. (U. S. Patent No. 6,167,689) under 35 U. S. C. 102(e).

(B) Whether claims 4-11are anticipated by Hirota et al. (U. S. Patent No. 5,201,802) under 35 U. S. C. 102(b).

(7) <u>Grouping of claims</u>

Group I -Claim 1

Group II- Claim 4.

Group III- Claim 5

Group IV- Claim 6

Group V -Claim 7

Group VI- Claim 8

Group VII- Claim 9
Group VIII- Claim 10

Group IX- Claim 11.

The claims in Groups I through IX do not rise or fall together.

(8) Argument

Applicant first wishes to discuss three points.

1. LIGHT-OFF

The term "light-off" refers to a specific **event**. It is not a temperature range, but rather a ***specific event*** that typically occurs **once per key-on session**. The method and system according to the invention inject the hydrocarbon into the engine exhaust in accordance with detection of a light-off **event.** The **light-off *event*** can be detected because when there is a hydrocarbon-O2 reaction (i.e., the exotherm is generated by the reaction of HC with O2, not with NOx), such reaction is an exothermic reaction and thus heat is generated and given off. The generation of such heat may be detected by measuring the difference in temperature across the catalyst. The peak in NOx conversion efficiency temperature changes with age. However, **because the peak in NOx conversion efficiency *temperature* occurs at substantially *the same temperature as light off event,*** a determination of light-off by the system and method enables adjustment in the hydrocarbon injection level for maximum NOx reduction efficiency.

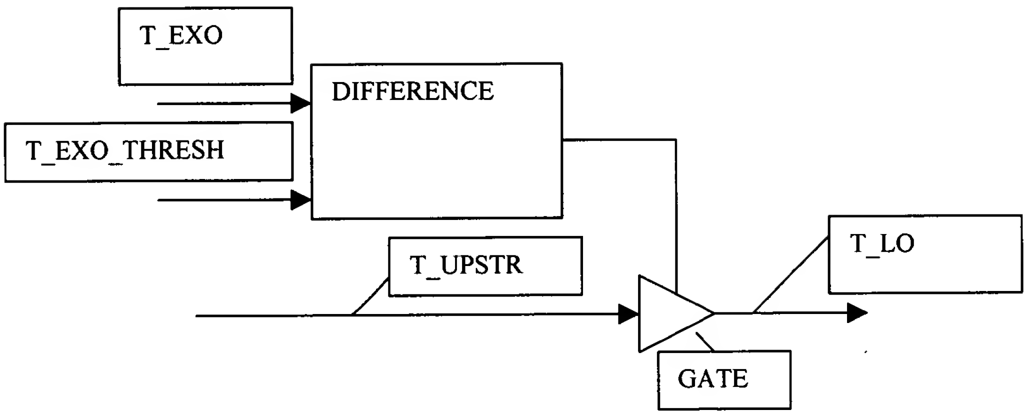
Thus, LIGHT-OFF refers to an EVENT not a temperature RANGE, as described by the Examiner.

2. The phrase "DETECTING A TEMPERATURE OF AN OUTPUT OF THE CATALYST IN RESPONSE TO THE DETECTED EXOTHERMIC REACTION "

measured ΔT ?

With the present invention, the difference between T_EXO and T_EXO_THRESH is used to detect a light-off EVENT. When such light-off EVENT is detected such detection serves as a gating signal to gate the temperature at the output of the catalytic converter, i.e., the temperature T_UPSTR, through gate 30 to provide the light-off temperature, T_LO. The EVENT detection process is illustrated below:

—


T_EXO
DIFFERENCE
T_EXO_THRESH
T_UPSTR
T_LO
GATE

Note that the event occurs only when T_EXO exceeds T_EXO_THRESH. It is also noted that when such occurs the temperature at the output of the catalytic converter, i.e., the temperature T_UPSTR, passes through gate 30 to provide the light-off ***temperature***, T_LO. Again, the provided light-off temperature is an ***actual temperature***, NOT A TEMPERATURE RANGE.

3. COMMENTS ON EXAMINER'S FINAL REJECTION

The Examiner has indicated that Applicant's "sketch fails to show a desired exothermic condition outlet temperature (T2) which is clearly shown as step 614 in Figure 14 of Hirota et al. This temperature T2 is the same as T_LO in the pending patent application."

As will be discussed in more detail below, T2 is, as stated in Hirota et al, at column 9, lines 43-44: " ...an upper limit T2 of an object temperature range .." .

As noted above, an event occurs only when T_EXO exceeds T_EXO_THRESH. It is also noted that when such occurs the temperature at the output of the catalytic converter, i.e., the temperature T_UPSTR, passes through gate 30 to provide the light-off ***temperature***, T_LO. Again, the provided light-off temperature is an ***actual temperature***, NOT A TEMPERATURE RANGE. Such process is not described in Hirota et al. Thus, T_LO is the temperature of the catalyst when T_EXO exceeds T_EXO_THRESH. It is not the same as T2 because T2 is the upper limit of a temperature range and not a temperature of the catalyst when T_EXO exceeds T_EXO_THRESH.

DISCUSSION OF THE CLAIMS AND HOW THEY DISCTINGUISH FROM King et al. and Hirota et al.

CLAIM 1- Claim 1 stands rejected as being anticipated by King et al. Claim 1 includes injecting the hydrocarbon into the engine in accordance with detection of a light-off ***event***. Such process is not described in King et al.

Referring now to U. S. Patent No. 6,167,698 (King et al.), particularly col, 3 line 14 through column 3 line 38:

> The operation of the exhaust gas purification system will now be described with reference to FIGS. 1 and 2. Pressurized air from the turbocharger compressor 31 fills the reservoir 30. The check valve 32 keeps the pressurized air from bleeding out of the reservoir and back into the compressor 31. As shown in FIG. 2, the engine control unit senses the upstream and downstream temperature of the catalyst 40 in step 100, by way of the upstream and downstream temperature sensors 50, 52 respectively. The upstream and downstream temperature sensors 50, 52 aid the engine control unit 18 in determining whether or not reductant is to be injected into the exhaust gas flow. For example, there are times such engine cold start operation, or extended idle, when the catalyst 40 is relatively cool and outside its prime operating mode and does not require reductant injection because of the relatively higher concentrations of unburned hydrocarbons in the exhaust gas flow. By known methods, the engine control unit 18 determines when it is necessary to add reductant to the exhaust gas flow at step 102.
>
> Although the preferred system includes temperature sensors 50, 52, alternative exhaust system sensors may be used. For example, upstream and downstream NO sensors could be used to directly measure the catalyst conversion efficiency.

It is respectfully submitted that nothing in King et al. describes injecting the hydrocarbon into the engine ***in accordance with detection of a light-off EVENT***. It is therefore respectfully submitted that claim1 is not anticipated by King et al.

CLAIMS 4-11- Claims 4-11 stand rejected as being anticipated by U. S. Patent No. 5,201,8002 (Hirota et al.)

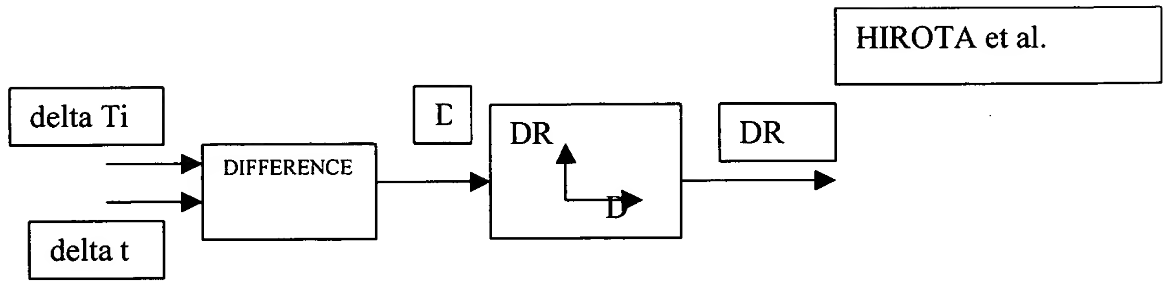
Considering now U.S. Patent No. 5,201,802 (Hirota et al.), as described beginning at column 9, lines 10 through line 55:

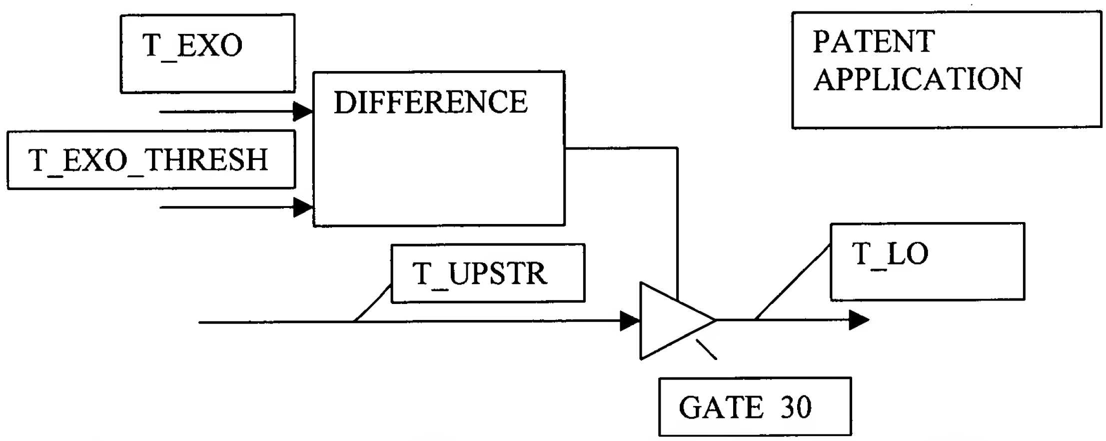
FIG. 14 illustrates a routine for determining degradation of the lean NOx catalyst 6. This routine is entered at intervals of predetermined periods of time, for example, at intervals of fifty milliseconds. At step 602, a determination is made as to whether or not the current engine operating condition is in a catalyst degradation determining condition, for example, in a warmed-up and usual running condition. If the current condition is not in the catalyst degradation determining condition, the routine returns. If the current condition is in the catalyst degradation determining condition, the routine proceeds to step 604, where the current engine load Q/N and the current engine speed NE are entered. Then, at step 606, a predetermined reference temperature difference (delta Ti) between the inlet gas and the outlet gas of the lean NOx catalyst 6, which corresponds to the engine load and engine speed conditions, is read from a map of FIG. 15.

Then, at step 608, the difference between the current inlet gas temperature t1 (output of the temperature sensor 24) and the current outlet gas temperature t2 (output of the temperature sensor 20) of the lean NOx catalyst 6 is calculated using the equation delta t=t2-t1. Then, at step 610, a catalyst degradation function D is calculated as a difference between the current temperature difference delta t and the reference temperature difference delta Ti using the equation D=delta Ti-delta t. Then, at step 612, a catalyst degradation extent DR is calculated using a map of DR versus D map of FIG. 16. In this instance, the steps 604 through 612 and FIG. 16 constitute the means for determining degradation of the lean NOx catalyst 6 in the third embodiment.

Then, at step 614, a lower limit T1 and an upper limit T2 of an object temperature range for the catalyst 6 are calculated based on the catalyst degradation extent DR using a map of object temperature range versus catalyst degradation extent of FIG. 17. In FIG. 17, there is a relationship between the temperatures T1 and T2 and the degradation extent DR such that the larger the value DR is, the higher the temperatures T1 and T2 are. Then, at step 616, the lower limit of the object temperature range TC is replaced by the calculated T1 and the upper limit of the range TH is replaced by T2. The control of catalyst temperature is executed according to the routine of FIG. 4 which was discussed. Then, the routine proceeds to step 618, where an object HC concentration H1 is calculated using the map of H1 versus DR of FIG. 18. In FIG. 18, there is a relationship between the object HC concentration H1 and the degradation extent DR such that the larger the DR is, the higher the HC concentration H1 is. At step 620, the object HC concentration HT is replaced by the calculated H1. The control of the HC amount is executed using the routine of FIG. 5 which was discussed. In this instance, the steps 618 and 620 and FIG. 18 constitute the means for increasing the amount of hydrocarbons supplied to the lean NOx catalyst 6 in the third embodiment. Further, the steps 614 and 616 and FIG. 17 constitute the means for increasing the catalyst temperature when the catalyst 6 has been degraded in the third embodiment. (emphasis added)

A comparison between the description above in the Hirota et al. patent and the system described by the Applicant above is summarized in the sketch below:





Thus, in Hirota et al. the difference between delta Ti and delta t provides D and D is used as an input to a lookup table to find DR. As pointed out at column 9, lines 42-47:

> ***Then, at step 614, a lower limit T1 and an upper limit T2 of an object temperature range for the catalyst 6 are calculated based on the catalyst degradation extent DR using a map of object temperature range versus catalyst degradation extent of FIG. 17.*** In FIG. 17, there is a relationship between the temperatures T1 and T2 and the degradation extent DR such that the larger the value DR is, the higher the temperatures T1 and T2 are.

Thus, DR is used to determine an upper limit T1 and a lower limit T2 (i.e., a ***RANGE***).

Hirota et al, does not determine an exothermic condition ***temperature*** at an output of the catalyst when the temperature difference is determined to exceed the threshold. Rather, as pointed about above, Hirota et al finds ***DR and DR is used to determine an upper limit T1 and a lower limit T2*** (i.e., a ***RANGE***) NOT " exothermic condition ***temperature.***

With the present invention, on the other hand, the difference between T_EXO and T_EXO_THRESH is used to detect a light-off condition and when such light-off condition is detected such detection serves as a gating signal to gate the temperature an the light-off

temperature, T_lo, (i.e., the temperature produced by the upstr sensor 20 when the computed exotherm T_exo exceeds the threshold level T_exo_thres) through the gate 30 to a subtractor 32. Thus, the gate 30 is an enabled gate to close temporarily when its enabling input exhibits a rising edge from negative to positive; otherwise it is open. This light-off temperature, T_lo which passes through gate 30 when such gate is temporarily closed, is compared with the light-off temperature expected for the catalyst 24 when such catalyst 24 was green; i.e., an expected light-off temperature T_lo_exp_green.

As noted above, the event occurs only when T_EXO exceeds T_EXO_THRESH. It is also noted that when such occurs the temperature at the output of the catalytic converter, i.e., the temperature T_UPSTR, passes through gate 30 to provide the light-off ***temperature***, T_LO. Again, the provided light-off temperature is an ***actual temperature***, NOT A TEMPERATURE RANGE.

As noted above, the Examiner has indicated that Applicant's "sketch fails to show a desired exothermic condition outlet temperature (t2) which is clearly shown as step 614 in Figure 14 of Hirota et al. This temperature T2 is the same as T_LO in the pending patent application."

From the discussion above, T2 is, as stated in Hirota et al, at column 9, lines 43-44: " ...an upper limit T2 of an object temperature range .." .

As noted above, an event occurs only when T_EXO exceeds T_EXO_THRESH. It is also noted that when such occurs the temperature at the output of the catalytic converter, i.e., the temperature T_UPSTR, passes through gate 30 to provide the light-off ***temperature***, T_LO. Again, the provided light-off temperature is an ***actual temperature***, NOT A TEMPERATURE RANGE. Such process is not described in Hirota et al. Thus, T_LO is the temperature of the catalyst when T_EXO exceeds T_EXO_THRESH. It is not the same as T2 because T2 is the upper limit of a temperature range and not a temperature of the catalyst when T_EXO exceeds T_EXO_THRESH.

Claim 4 includes "(b) detecting a temperature of an output of the catalyst in response to the detected exothermic reaction". (emphasis added). As noted above, the event occurs only when T_EXO exceeds T_EXO_THRESH. It is also noted that when such occurs the temperature at the output of the catalytic converter, i.e., the temperature T_UPSTR, passes

through gate 30 to provide the light-off ***temperature***, T_LO. Again, the provided light-off temperature is an ***actual temperature***, NOT A TEMPERATURE RANGE.

Such process is not described in Hirota et al.

Claim 5 includes:

(c) determining an exothermic condition ***temperature*** at an output of the catalyst when the temperature difference is determined to exceed the threshold;
(d) comparing the determined exothermic condition temperature with an exothermic condition temperature expected from the catalyst at a time prior to the determined exothermic condition temperature; and
(e) modifying the injected hydrocarbon in accordance with said comparison. (emphasis added)

Thus, referring to FIG. 2. the determined exothermic condition temperature (T_UPSTR at light-off (i.e., T_LO) is compared with T_LO_EXP_GREEN. Hirota et al, does not determine an exothermic condition temperature at an output of the catalyst when the temperature difference is determined to exceed the threshold; comparing the determined exothermic condition temperature with an exothermic condition temperature expected from the catalyst at a time prior to the determined exothermic condition temperature; and modify the injected hydrocarbon in accordance with said comparison, as claimed in set forth in claim 5.

As noted above, the event occurs only when T_EXO exceeds T_EXO_THRESH. It is also noted that when such occurs the temperature at the output of the catalytic converter, i.e., the temperature T_UPSTR, passes through gate 30 to provide the light-off ***temperature***, T_LO. Again, the provided light-off temperature is an ***actual temperature***, NOT A TEMPERATURE RANGE. Such process is not described in Hirota et al.

Claim 6 includes:

(b) comparing the temperature difference with a predetermined temperature threshold;

(c) determining an exothermic condition ***temperature*** at an output of the catalyst when the temperature difference is determined to exceed the threshold. (emphasis added).

As noted above, the event occurs only when T_EXO exceeds T_EXO_THRESH. It is also noted that when such occurs the temperature at the output of the catalytic converter, i.e., the temperature T_UPSTR, passes through gate 30 to provide the light-off ***temperature***, T_LO. Again, the provided light-off temperature is an ***actual temperature***, NOT A TEMPERATURE RANGE.

Such process is not described in Hirota et al.

Claim 7 points out that processor being programmed to:

compare a difference in the common parameter detected by the pair of sensors with a predetermined threshold;

determine an ***exothermic condition*** at an output of the catalyst when the difference in the common parameter is determined to exceed the threshold;

compare the determined exothermic condition with an exothermic condition expected from the catalyst at a time prior to the determined exothermic condition; and

modify the injected hydrocarbon in accordance with said last-mentioned comparison.

As noted above, the event occurs only when T_EXO exceeds T_EXO_THRESH. It is also noted that when such occurs the temperature at the output of the catalytic converter, i.e., the temperature T_UPSTR, passes through gate 30 to provide the light-off ***temperature***, T_LO. Again, the provided light-off temperature is an ***actual temperature***, NOT A TEMPERATURE RANGE.

Claim 8 points out that the common parameter is temperature.. As noted above, the event occurs only when T_EXO exceeds T_EXO_THRESH. It is also noted that when such occurs the temperature at the output of the catalytic converter, i.e., the temperature T_UPSTR, passes through gate 30 to provide the light-off ***temperature***, T_LO. Again, the provided light-off temperature is an ***actual temperature***, NOT A TEMPERATURE RANGE. Such process is not described in Hirota et al.

Claim 9 points out that the control signal is provided by steps comprising:

> comparing a difference in the common parameter detected by the pair of sensors with a predetermined threshold;
>
> determining an exothermic condition at an output of the catalyst when the difference in the common parameter is determined to exceed the threshold;
>
> comparing the determined exothermic condition with an exothermic condition expected from the catalyst at a time prior to the determined exothermic condition; and
>
> modifying the injected hydrocarbon in accordance with said last-mentioned comparing.

As noted above, the event occurs only when T_EXO exceeds T_EXO_THRESH. It is also noted that when such occurs the temperature at the output of the catalytic converter, i.e., the temperature T_UPSTR, passes through gate 30 to provide the light-off ***temperature***, T_LO. Again, the provided light-off temperature is an ***actual temperature***, NOT A TEMPERATURE RANGE. Such process is not described in Hirota et al.

Claim 10 includes comparing a difference in a common parameter detected by a pair of sensors with a predetermined threshold, one of such sensors being upstream of the catalyst and the other one of the sensors being downstream of the first sensor; determining an exothermic condition at an output of the catalyst when the difference in the common parameter is determined to exceed the threshold; comparing the determined exothermic condition with an exothermic condition expected from the catalyst at a time prior to the determined exothermic condition; and modifying the injected hydrocarbon in accordance with said last-mentioned comparison.

Claim 11 points out that the common parameter is temperature.. As noted above, the event occurs only when T_EXO exceeds T_EXO_THRESH. It is also noted that when such occurs the temperature at the output of the catalytic converter, i.e., the temperature T_UPSTR, passes through gate 30 to provide the light-off ***temperature***, T_LO. Again, the provided light-off temperature is an ***actual temperature***, NOT A TEMPERATURE RANGE. Such process is not described in Hirota et al.

Any questions regarding this matter may be directed to the undersigned. In the event any additional fee is required, please charge such amount to the Patent and Trademark Office Deposit Account No. 50-0845.

Respectfully submitted,

11/12/02
Date

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(9) Appendix

PENDING CLAIMS

1. A method for controlling hydrocarbon injection into an engine exhaust to reduce NOx, comprising:

injecting the hydrocarbon into the engine exhaust in accordance with detection of a light-off event.

4. A method for controlling hydrocarbon injection into an engine exhaust to reduce NOx in such exhaust, such engine exhaust with the NOx and the injected hydrocarbon being directed to a catalyst for reaction therein, comprising:

look like claim 1

(a) detecting an exothermic reaction across the catalyst; and

(b) detecting a temperature of an output of the catalyst in response to the detected exothermic reaction; and

(c) injecting the hydrocarbon into the reaction in accordance with the detected temperature.

5. (Amended) A method for controlling hydrocarbon injection into an engine exhaust to reduce NOx in such exhaust, such engine exhaust with the NOx and the injected hydrocarbon being directed to a catalyst for reaction therein, comprising:

(a) detecting a temperature difference across the catalyst;

(b) comparing the temperature difference with a predetermined temperature threshold;

(c) determining an exothermic condition temperature at an output of the catalyst when the temperature difference is determined to exceed the threshold;

(d) comparing the determined exothermic condition temperature with an exothermic condition temperature expected from the catalyst at a time prior to the determined exothermic condition temperature; and

(e) modifying the injected hydrocarbon in accordance with said last-mentioned comparison.

6. A method for determining peak efficiency temperature of a catalyst in reducing NOx wherein such NOx is reduced by reacting such NOx in the catalyst with a hydrocarbon, comprising:

(a) detecting a temperature difference across the catalyst;

(b) comparing the temperature difference with a predetermined temperature threshold;

(c) determining an exothermic condition temperature at an output of the catalyst when the temperature difference is determined to exceed the threshold.

7. (Amended) A system for controlling hydrocarbon injection into an engine exhaust to reduce NOx in such exhaust, such engine exhaust with the NOx and the injected hydrocarbon being directed to a catalyst for reaction therein, comprising:

(a) a catalyst for facilitating a reaction between the injected hydrocarbon and NO_x in the exhaust;

(b) a hydrocarbon injector for injecting the hydrocarbon into the exhaust upstream of the catalyst;

(c) a detecting system comprising:

a pair of sensors each detecting a common parameter in the exhaust, one of such sensors being upstream of the catalyst and the other one of the sensors being downstream of the first sensor; and

a processor for controlling the hydrocarbon injector in response to the pair of sensors, such processor being programmed to:

compare a difference in the common parameter detected by the pair of sensors with a predetermined threshold;

determine an exothermic condition at an output of the catalyst when the difference in the common parameter is determined to exceed the threshold;

compare the determined exothermic condition with an exothermic condition expected from the catalyst at a time prior to the determined exothermic condition; and

modify the injected hydrocarbon in accordance with said last-mentioned comparison.

8. The system recited in claim 7 wherein the common parameter is temperature and wherein the sensors are temperature sensors.

9. A processor for controlling hydrocarbon injection into an engine exhaust to reduce NOx in such exhaust, such engine exhaust with the NOx and the injected hydrocarbon being directed to a catalyst to facilitate reaction between the injected hydrocarbon and the exhaust NOx, such processor being programmed to:

provide a control signal to a hydrocarbon injector to inject the hydrocarbon into the exhaust upstream in response to output signal from a pair of sensors, each of the pair of sensors being adapted detecting a common parameter in the exhaust, one of such sensors being upstream of the catalyst and the other one of the sensors being downstream of the first sensor, such control signal being provided by steps comprising:

comparing a difference in the common parameter detected by the pair of sensors with a predetermined threshold;

determining an exothermic condition at an output of the catalyst when the difference in the common parameter is determined to exceed the threshold;

comparing the determined exothermic condition with an exothermic condition expected from the catalyst at a time prior to the determined exothermic condition; and

modifying the injected hydrocarbon in accordance with said last-mentioned comparing.

10. A method for controlling hydrocarbon injection into an engine exhaust to reduce NOx in such exhaust, such engine exhaust with the NOx and the injected hydrocarbon being directed to a catalyst for reaction therein, comprising:

comparing a difference in a common parameter detected by a pair of sensors with a predetermined threshold, one of such sensors being upstream of the catalyst and the other one of the sensors being downstream of the first sensor;

determining an exothermic condition at an output of the catalyst when the difference in the common parameter is determined to exceed the threshold;

comparing the determined exothermic condition with an exothermic condition expected from the catalyst at a time prior to the determined exothermic condition; and

modifying the injected hydrocarbon in accordance with said last-mentioned comparison.

11. The method recited in claim 10 wherein the common parameter is temperature and wherein the sensors are temperature sensors.